DOCUMENT RESUME

ED 127 165 SE 021 202

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TITLE MINNEMAST Recommendations for Science and Math in the Intermediate Grades.
INSTITUTION Minnesota Univ., Minneapolis. Minnesota School Mathematics and Science Center.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE 70
NOTE 55p.; For related documents, see SE021201-234; Photographs may not reproduce well
AVAILABLE FROM MINNEMAST, Minnemath Center, 720 Washington Ave., S.E., Minneapolis, MN 55414

EDRS PRICE MF-$0.83 HC-$3.50 Plus Postage.
DESCRIPTORS *Curriculum; Curriculum Planning; Elementary Education; *Elementary School Mathematics; *Elementary School Science; *Instructional Materials; *Interdisciplinary Approach; Intermediate Grades; Mathematical Applications; Mathematics Education; Process Education; Science Education; Textbooks
IDENTIFIERS *MINNEMAST; *Minnesota Mathematics and Science Teaching Project

ABSTRACT

This volume provides recommendations for teaching mathematics and science to intermediate students who have been taught using the MINNEMAST materials during the primary grades. After reviewing briefly the goals and content of the primary curriculum, the authors discuss the transitions from the integrated program to distinct curricula in mathematics and science. For each field, several criteria for the intermediate curriculum are defined and alternate models are offered. Text and supplementary materials are suggested for each of these models. Brief descriptions of the recommended texts are provided. (SD)

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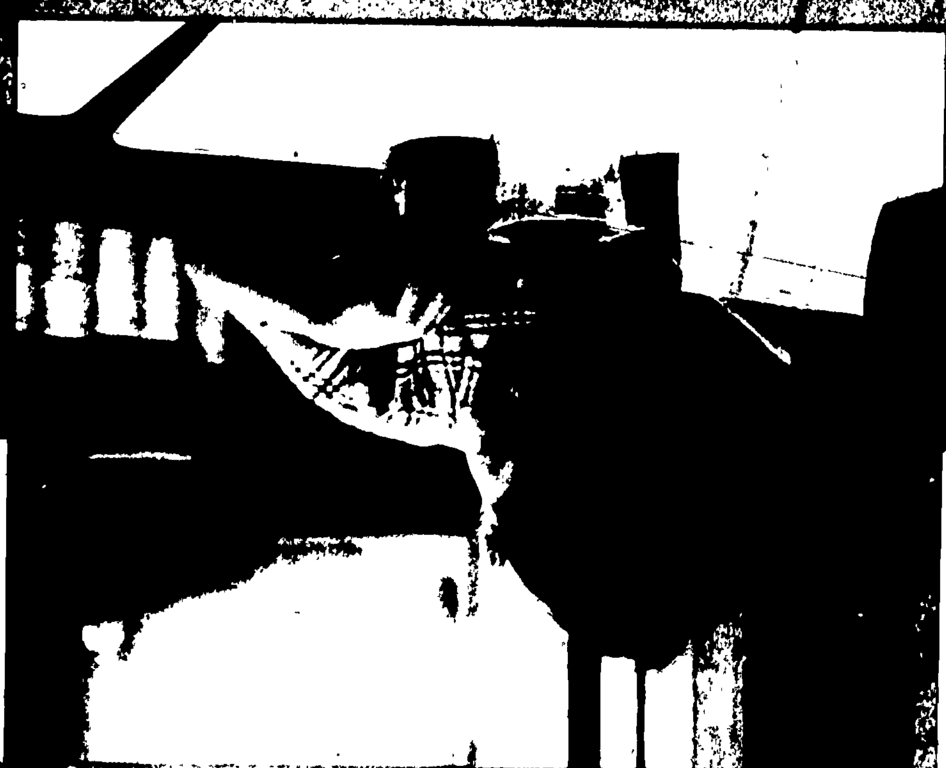

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The Minnesota Mathematics and Science Teaching Project produced this booklet under a grant from the National Science Foundation

RECOMMENDATIONS
for Science and Math in the Intermediate Grades

by:
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FOREWORD

Mathematicians, scientists and educators combined their talents to produce the 29 sequential units that make up the MINNEMAST Curriculum. They have coordinated the teaching of mathematics with the teaching of science in kindergarten and the primary grades.

This coordinated curriculum provides a firm foundation on which the children can build as they follow other mathematics and science non-coordinated curricula in fourth grade and later. We place special emphasis on the actual handling of materials by the students, which leads to a fundamental understanding of concepts, as opposed to rote learning. Through actual experience the children see how math and science serve each other and how closely interrelated they are. We think that mathematics and science taught as totally unrelated subjects cannot provide as good a preparation as with this approach.

If your school or your district is not presently employing the MINNEMAST Curriculum, we heartily invite and encourage you to examine it and to consider its adoption. A pamphlet, Questions and Answers about MINNEMAST, and a price list will be sent free upon request. Our Overview, which provides an illustrated description of the contents of each unit and our auxiliary books, is obtainable at modest cost. You will find the Overview very helpful, we think, in any preliminary investigation of our materials. Any of our publications may be purchased singly. Many are useful and rewarding at levels other than those indicated in our sequential arrangement.

CONTENTS

MINNEMAST

COORDINATED MATHEMATICS–SCIENCE SERIES

KINDERGARTEN

FIRST GRADE

SECOND GRADE

THIRD GRADE

1. WATCHING AND WONDERING
2. CURVES AND SHAPES
3. DESCRIBING AND CLASSIFYING
4. USING OUR SENSES
5. INTRODUCING MEASUREMENT
6. NUMERATION
7. INTRODUCING SYMMETRY
8. OBSERVING PROPERTIES
9. NUMBERS AND COUNTING
10. DESCRIBING LOCATIONS
11. INTRODUCING ADDITION AND SUBTRACTION
12. MEASUREMENT WITH REFERENCE UNITS
13. INTERPRETATIONS OF ADDITION AND SUBTRACTION
14. EXPLORING SYMMETRICAL PATTERNS
15. INVESTIGATING SYSTEMS
16. NUMBERS AND MEASURING
17. INTRODUCING MULTIPLICATION AND DIVISION
18. SCALING AND REPRESENTATION
19. COMPARING CHANGES
20. USING LARGER NUMBERS
21. ANGLES AND SPACE
22. PARTS AND PIECES
23. CONDITIONS AFFECTING LIFE
24. CHANGE AND CALCULATIONS
25. MULTIPLICATION AND MOTION
26. WHAT ARE THINGS MADE OF?
27. NUMBERS AND THEIR PROPERTIES
28. MAPPING THE GLOBE
29. NATURAL SYSTEMS

OTHER MINNEMAST PUBLICATIONS

The 29 coordinated units and several other publications are available from MINNEMAST on order. Other publications include:

STUDENT MANUALS for Grades 1, 2 and 3, and
printed TEACHING AIDS for Kindergarten and Grade 1.

LIVING THINGS IN FIELD AND CLASSROOM
(MINNEMAST Handbook for all grades)

ADVENTURES IN SCIENCE AND MATH
(Historical stories for teacher or student)

QUESTIONS AND ANSWERS ABOUT MINNEMAST
Sent free with price list on request

OVERVIEW
(Description of content of each publication)

MINNEMAST RECOMMENDATIONS FOR SCIENCE AND MATH IN THE INTERMEDIATE GRADES
(Suggestions for programs to succeed the MINNEMAST Curriculum in Grades 4, 5 and 6)

For additional information, a price list and orders, write to:

MINNEMAST Director
Minnemath Center
720 Washington Ave. S. E.
Minneapolis, Minnesota 55414

PURPOSE OF THIS BOOKLET

Many thousands of children are studying or have studied science and math via the MINNEMAST Coordinated K-3 Curriculum. Many more will be entering our program in the future. We have had numerous requests from educators interested in continuing MINNEMAST objectives and techniques through the intermediate grades for suggestions concerning materials we think appropriate. The MINNEMAST staff, too, is much concerned with the kind of science and math education that MINNEMAST children will receive in Grades 4, 5 and 6. We should like to see the positive attitudes toward science and math that the children acquire in our program continue to grow. We should also like to see the special concepts and skills the children develop by the end of Grade 3 put to advantageous use in the next grades. We believe that the intermediate grades offer great opportunities for the application of our children's skills. For these reasons, staff members have examined all of the leading science and math curricula (both project and commercial) for the intermediate grades.

Because MINNEMAST is unique in coordinating science and math, we found no single curriculum that fulfilled — by itself — all of the MINNEMAST requirements; but neither did we see any particular problems in switching to non-coordinated materials for Grades 4, 5 and 6. In fact, we feel that our program gives children, in these most important early years, a better preparation for the more difficult work of the intermediate grades than can be provided by non-coordinated materials.

In this booklet the authors suggest a number of alternatives for the continuing education of MINNEMAST children. Our suggestions are intended to be helpful rather than dogmatic. Curricula not mentioned by us may prove to be more suitable for certain local conditions, and educators are encouraged to survey other materials for themselves to see if this may be so. Also, our failure to mention any particular curriculum is by no means to be interpreted as a criticism of it. We are merely presenting here, for your consideration, recommendations of materials that seem to be adequate successors to our curriculum.

To make clear the criteria by which MINNEMAST staff members made their selections, we present first a short summary of the project's objectives, techniques and curriculum.

The Minnesota Mathematics and Science Teaching Project (MINNEMAST) is the only major project established for the express purpose of coordinating the teaching of science and the teaching of mathematics in the elementary grades. In recent years the National Science Foundation has provided the funds. The result is a curriculum of 29 units extending from Kindergarten through Grade 3. In addition to the teaching units, Student Manuals have been provided for Grades 1, 2 and 3. For Kindergarten and Grade 1, various printed Teacher Aids have also been prepared. (Many school systems have no kindergarten classes. In these cases, the teachers select key lessons from the kindergarten materials to present at the beginning

of the first grade. Because of the greater maturity of first graders, the kindergarten lessons are quickly mastered.) We have also published two auxiliary books: (1) Living Things in Field and Classroom is useful at all elementary levels; and (2) Adventures in Science and Math can be used by both teacher and student at different levels to provide motivation and enrichment.

The principal aims of the MINNEMAST Project are:

- to develop competency in both mathematics and science,
- to provide experiences that involve the students in challenging and interesting problem-solving situations, and
- to provide settings that enable the children to explore, discover and clarify the relationships between mathematics and science wherever feasible.

Why coordinate mathematics and science?

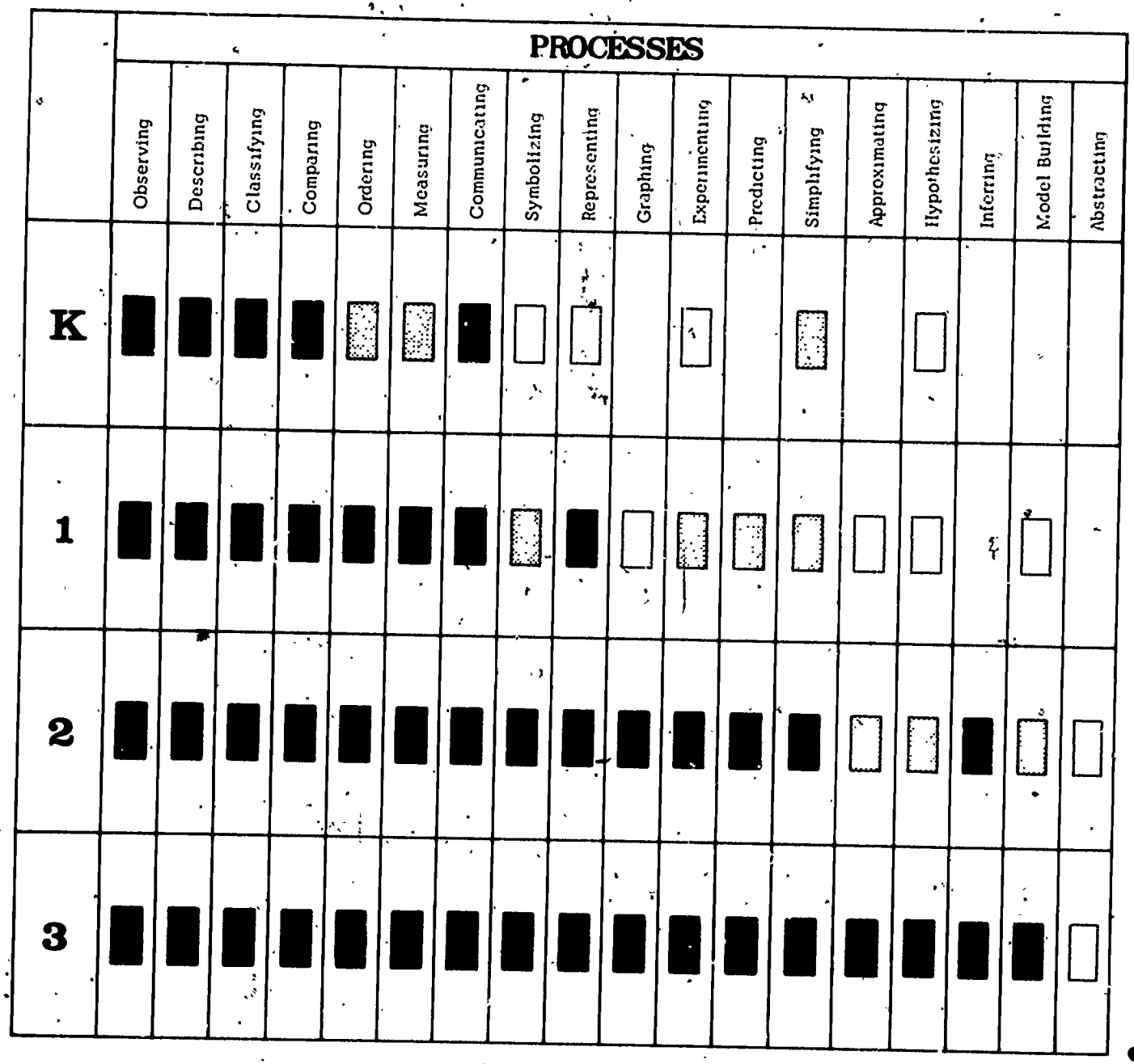
There are many natural bridges between mathematics and science. In fact, the science that we know and wish to communicate to children today would not even exist without the clarification and precision that mathematics provides. And much theoretical science has evolved, in a sense, from branches of applied mathematics. The dependence of mathematics on science is not so explicit, for mathematics in its purest form is basically inde-

pendent of science. However, the many discoveries and demands for quantification in the various sciences provide a great impetus to the advancement of mathematics. Because of these valid relations between the two disciplines, project planners and writers believe that an early coordinated approach helps children see the interrelationships and develop a stronger and deeper understanding of both fields of study. We also believe that this coordination leads to an earlier appreciation of the principles on which the world operates, enabling children to understand, and sometimes even predict, various changes.

Project writers have been successful in finding many relationships for the children to explore. The MINNEMAST treatment of concepts dealing with measurement, sets, symmetry, slope, density and systems, as well as our development of techniques for accurate observation and description, exemplify areas that allow the children to uncover and exploit interrelationships between the two disciplines.

The chart on the following pages shows the principal concepts and skills emphasized at different levels of the MINNEMAST Curriculum. It should be helpful to educators in selecting materials for the intermediate grades that build on and make use of what MINNEMAST children have already learned. A more detailed chart, "Threads That Run Through the MINNEMAST Curriculum," is provided near the end of this booklet on pp. 48 and 49.

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT



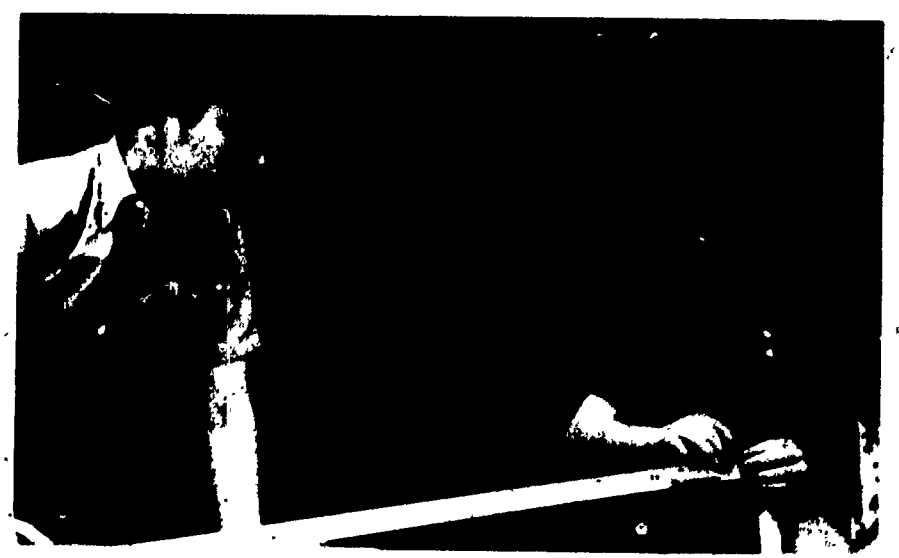
Key to processes: Introduced ☐ Applied ▨ Extended and applied ■

CONTENT

Content topics are selected for:

1. age-grade appropriateness
2. concept development
3. process application

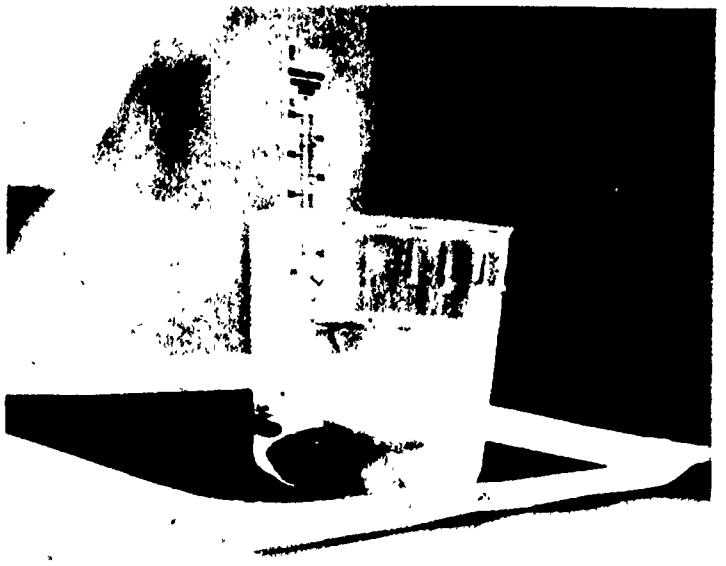
sets and groups shapes symmetry one to one correspondence developing number concept equivalent sets	using senses measurement indoor-outdoor observing
sets - intersections and unions set and number line interpretations of addition and subtraction geometry - describing locations equivalence of sets developing number concept ordering	measurement of length, area, volume, time duration changing properties of ice cubes, seeds, plants, mealworms frames of reference symmetry
use fractional units in measurement review and extending addition and subtraction concepts multiply and divide small whole numbers scaled diagrams and models geometry - review, angles and their measure, polygons and polyhedra graphing	functional relationships systems - natural and contrived measurement of weight interpretation of graphs
review and extend place value measurement geometry - mapping extend concept and computation with rational numbers introduce the grid to interpret multiplication graphing extending multiplication	conditions affecting life motion investigation of materials




My Hardness Scale

Because MINNEMAST coordinated the teaching of mathematics with the teaching of science, many of the objectives and methods used were employed in the teaching of both disciplines. These were described in the preceding pages. But, no doubt, educators who specialize in mathematics will be more interested in this section of the document, while science educators will be concentrating on the "Science Transitional Statement." Because of the similarity of our MINNEMAST learning/teaching mode for both subjects, there will be some overlap in the information provided. However, for your convenience, we are reiterating here some facts particularly as they pertain to mathematics.

In mathematics, as in science, the MINNEMAST Project places great emphasis on student involvement in the learning process. The adage that "children learn by doing" has been taken seriously and it has been kept in mind all through the preparation of the materials. As a result, MINNEMAST students are, more often than not, actively engaged in the solution of some problem that has been designed to have relevance for them. They may be attempting to predict the growth rate of plants under various growing conditions, to determine the effect that temperature has on the behavior of goldfish, or to explore the relationship between the weight and volume of various substances. The quantification of such physical phenomena is a powerful tool that man has developed to aid him to understand more fully these and numerous other relationships that abound in



the world. The power and utility of this tool is established early in the program. Thus there evolves one of the most important relationships between mathematics and science, the use of mathematics to describe and explicate the results of scientific inquiry. The development and implementation of this idea has played no small part in the development of the MINNEMAST materials. As a result, our students tend to view mathematics as both a "living" subject having great utility and as a kind of game whose pieces behave in a very predictable manner — adhering to rules which they have been instrumental in developing. This is in contrast to the frequently held student view of mathematics as a set of rules to be memorized and applied under appropriate stimuli. Project members are hopeful that the mathematics program chosen for MINNEMAST children in the intermediate grades will have inherent in it much of the former emphasis and little, if any, of the latter.

Webster defines arithmetic as "a branch of mathematics that deals with real numbers and computations with them, i.e. computation, calculation," while mathematics is defined as "the science of numbers and their operations, interrelations, combinations, generalizations and abstractions and of space configurations, configurations and their structure, measurement, transformations and generalizations." Applying this definition, the MINNEMAST Project has been primarily concerned with the provision of a mathematics program although arithmetic implications have not been ignored.

Our project staff believes that the primary grades are the time for the implantation and preliminary development of appropriate major mathematical ideas, a time for the child to experience mathematical concepts, a time to observe, to wonder, to explore avenues of interest and appeal, a time to be involved in the rudiments of inductive thinking derived from experience with concrete media. Accordingly, we have placed emphasis on these areas rather than on computation and drill. The MINNEMAST Project has devoted its efforts to student understandings of fundamental mathematical (not merely arithmetical) ideas. The importance of computational facility is recognized, but it is felt that the development of these skills prior to the provision for multiple student opportunities to experience the concepts in concrete form is unwise from both a mathematical and pedagogical viewpoint.

As a result of this philosophy, MINNEMAST students have been exposed to elements of number theory, set theory, Euclidean and projective geometry, transformational geometry and the intuitive idea of a mathematical function. Besides, MINNEMAST students through the third grade level have worked with most of the arithmetical concepts found in traditional primary mathematics programs.

We believe that by providing considerable breadth in mathematics content and by continually placing emphasis on student discovery and understanding of logical relationships, MINNEMAST represents a closer approximation to a true math-

MATHEMATICS TRANSITION CRITERIA

ematics curricula than the vast majority of programs available. In searching for a reasonable successor to its primary mathematics program we have placed a high priority on:

- the suitability of included topics relative to continuation and expansion of fundamental concepts that MINNEMAST has begun to develop
- the degree to which student involvement is encouraged
- the extent to which students are encouraged to discover and develop mathematical ideas for themselves
- the degree of variation of mathematical topics
- the precision with which these topics are introduced and developed
- the degree of priority given to the development of computational facility.

Realizing its obligation to provide specific suggestions for the intermediate grades that continue to develop the mathematical ideas it has begun, the MINNEMAST Project has conducted a careful examination of the more popular mathematics commercial text series. The criteria stated above have formed the basis upon which these mathematical programs have been evaluated.

As mentioned previously, the MINNEMAST Project recognizes the importance of student involvement in learning activities. Commensurate with this recognition is our belief that children

should have the opportunity to develop ideas traditionally transmitted by rote. Probably no program has been successful in developing a totally discovery-oriented program, but MINNEMAST students do have many opportunities to formulate important ideas for themselves.

"Development of insight through discovery," "conceptual approach emphasizing discovery" and "problem-solving as discovery" are typical program descriptions found in the introductory pages of commercial text series. Our investigations have indicated that pupils are not involved in true discovery activities to the extent that such statements suggest. Discovery is a laudatory aim that is often minimized. Editorial pressures, standardized achievement tests, as well as concern for administrative and community anxiety, are factors that tend to limit severely the production of a truly process oriented commercial program. In attempting to select materials that offer continuing problem-solving challenges with emphasis on individual investigation and discovery, MINNEMAST suggests three models for your consideration. These models are recommended for use in Grades 4 through 6 by children who have used MINNEMAST materials through Grade 3. You will notice that each model includes supplementary material from the Madison Project. Although supplementary, this material is considered an important part of any of the three models we have proposed. Therefore a description of the Madison Project is provided, along with a list of some of its materials, before the commercial text

series are described. The three models we are suggesting are listed here in alphabetical order:

Model 1

a) Elementary School Mathematics
Addison Wesley Company (1968)

b) Madison Project (Supplemental)

Model 2

a) Sets and Numbers
Singer Company (1968, 1969)

b) Madison Project (Supplemental)

Model 3

a) SRA Elementary Mathematics Program
Science Research Associates, Inc.
(1968, 1969)

b) Madison Project (Supplemental)

We do not intend that commercial series not mentioned above should be conspicuous by their absence. It is entirely possible that commercial materials other than those named will be more in keeping with local objectives. We would encourage local curriculum committees to examine additional materials to determine whether or not this is the case. The MINNEMAST staff is obligated to state, however, that the three text series mentioned above were not selected at random. Of all series examined, Singer, Addison Wesley and SRA were found to be the most consistent with the philosophy, aims, and the teaching-learning mode of the MINNEMAST program.

MINNEMAST mathematical skills and concepts are listed, unit by unit, on pages 28 through 32. This list can be used not only for assistance in determining which math program to select for the intermediate grades, but also for selecting individual MINNEMAST units to teach at other levels where it is felt there are certain gaps in the students' mathematical education. The list can be helpful in choosing units to include for study in math education courses, too.

SUPPLEMENTARY MATERIALS

The MINNEMAST Project was unable to locate a commercial text series that fully reflects the philosophy of mathematical learning to which it subscribes. Therefore, the desirability of supplementary materials was realized. The Madison Project materials have been designed to supplement (approximately 40 minutes per week) existing mathematics programs at the intermediate grade level. The objectives of the Madison Project were found to be largely consistent with the MINNEMAST philosophy from both a content and pedagogical viewpoint. The Madison Project materials are designed to allow schools to make certain modifications in their mathematics programs. The materials can be used for the following purposes:

- to provide a foundation for developing a K-8 program that unifies arithmetic, algebra, geometry, and some science
- to shift the tone and emphasis of the school's program away from rote learning and toward learning by processes

- to move toward a greater use of physical materials and multi-sensory experiences in mathematics classes
- to create greater opportunities for small-group work and individualized instruction
- to use a specific teaching strategy based on discussion of activities the children have done during an exploration period
- to create a more receptive environment for student initiative, especially where unexpected (but correct) responses are made by students
- to open the door to a reconsideration of the grade-level placement of many topics
- to open the door to a non-graded program
- to make available the simplest possible program for students who are not experiencing success with mathematics
- to make available a more sophisticated and a more advanced mathematics program for those students who can benefit from it.

Besides the similarity in teaching methods in the MINNEMAST and Madison Projects, the specific topics developed in the Madison Project materials are a natural extension of many threads that the MINNEMAST Project has initiated. Also, the Madison Project has realized the necessity in many instances of providing specific instructional suggestions for teachers not familiar with the materials. An extensive teacher in-service program complete with films and teacher workbooks accompanies the student materials. These in-service materials provide detailed suggestions and illustrations of the way in which the student

material can be most effectively taught. The Madison Project greatly simplifies the problem of in-service teacher training by providing the basic components of a complete instructional package for both teacher and students.

In particular, the Madison Project's Curriculum β (Beta) is recommended. This curriculum is made up of a combination of lessons developed by the Madison Project, the Elementary Science Study (ESS) and the Nuffield Project of Great Britain and by individuals such as Marion Walter, Lauren Woodby, Leonard Sealey, Z. P. Dienes, Edith Biggs and Geoffrey Matthews.

Curriculum Beta combines elements of carpentry, social studies, art and communication skills with mathematics and science. It is intended to reach a great diversity of children and appears to be able to do so.

Certain parts of Curriculum Beta can serve quite different purposes because of the variety of its content. The curriculum employs units developed by the Madison Project (especially those emphasizing arithmetic and geometry) as well as units devised by other individuals and groups. Some of the borrowed materials have been modified; others are used just as they are.

For those schools wishing an intermediate level mathematics program that is a logical successor to the MINNEMAST materials, the Madison Project is felt to be an essential element in any transitional model. It is hoped that school personnel responsible for this type of curricular

decision will seriously attempt to integrate these materials with whatever commercial program is ultimately adopted.

A much more complete description of the Madison Project is provided in Volumes I and II of its Final Report, "Modern Mathematics Program as it Pertains to the Interrelationship of Mathematical Content, Teaching Methods and Classroom Atmosphere." Here we shall content ourselves with adding only that Curriculum Beta is a non-text program using materials from a wide variety of sources. A partial list of the Madison Project materials follows.

(Selections of supplementary materials should be made and ordered well in advance of the dates they will be needed. For additional information, write to the addresses provided in this list.)

The Madison Project
918 Irving Avenue
Syracuse, New York 13210
(Telephone - Area Code 315, 476 - 3768 or 476 - 5541 X2336)

Actual classroom lessons of Curriculum Beta can be seen in the following films:

- Geometry Via Concrete Objects
  Gluing and Stamping
  Using Geoboards with Second Graders
  An Introduction to Geometry via Nailboards
  A Sixth-Grade Lesson on Place-Value Numerals
  The Concepts of Volume and Area
  The Classroom Divided into Small Groups

Counting, Volume and Rational Approximations
Small-Group Instruction
Signed Numbers, Rational Approximations and Motion Geometry
Outdoor Mathematics
A Lesson with Second Graders
Second Lesson
Guessing Functions
In-Service Course I for Teachers (combines films and printed material)

In addition to the films, Curriculum Beta offers units and devices of its own, as well as those borrowed or adapted from other sources. Note the following typical credits:

- Units have been borrowed from the Nuffield Mathematics Project; Mirror Cards and attribute blocks from ESS; and Informal Geometry from Marion Walter. Cuisenaire rods are also used.
- Units developed by Leonard Sealey, such as those on pronouncing and writing number names, are used in connection with Dienes' MAB blocks; and units by Edith Biggs, such as that in which geometric shapes are classified by using an assortment of common cardboard boxes, are also used.
- A wide variety of calculators is used. These include desk types such as the Lagomarsine, the Monroe, ten-key, full-keyboard, double-keyboard (often used by statisticians), those that print on paper strips, inexpensive plastic ones, manuals and electrics.

- Lauren Woodby's Outdoor Mathematics, which emphasizes measurement, ratio and proportion is a part of Curriculum Beta.
- Uses for Dienes' MAB blocks, other than those already mentioned, are included.
- Beryl Cochran's development of place-value numerals by the use of beans, tongue depressors, and so on, is a part of the curriculum.
- Included is the sine-generating machine developed by the Cambridge Conference on School Mathematics during the summer of 1967.
- The simple rough study of periodic functions, such as temperature at various hours of the day, was suggested by Professor Andrew Gleason of Harvard University.

Publications

- Inquiry in Mathematics via the Geo-Board, by Donald Cohen. (Available from Walker Co., 720 Fifth Avenue, New York, N. Y. 10019.)
- Explorations in Mathematics: A Text for Teachers
  Explorations in Mathematics: Student Discussion Guide
  Discovery in Mathematics: A Text for Teachers
  Discovery in Mathematics: Student Discussion Guide
  (All by Robert B. Davis. Available from Addison-Wesley Publishing Company, South Street, Reading, Massachusetts 01867.)

- I Do and I Understand
  Mathematics Begins
  Pictorial Representation
  Beginnings
  Computation and Structure 1, 2, 3, 4
  Shape and Size 1, 2, 3
  Environmental Geometry
  Probability and Statistics
  Graphs Leading to Algebra
  Problems: Green Set and Red Set
  (All of the above are products of the Nuffield Project of Great Britain. Available in the United States from John Wiley and Sons Publishing Company, 605 Third Avenue, New York, N. Y. 10016.)

Other Films

Three films not produced by the Madison Project are also highly recommended for expressing the mathematical concepts very clearly and for relating mathematical ideas to other areas of study. They are:

- I Do and I Understand (Available from Radim Films, 211 East 43rd Street, New York, N. Y. 10017.)
- Maths Alive (Available from National Audio-Visual Aids Library, 2 Paxton Place, Gypsy Road, London, S. E. 27, England.)
- Classrooms in Transition (Available from Mary Lela Sherburne, Education Development Center, Inc., 55 Chapel Street, Newton, Massachusetts 02158.)

RECOMMENDED
COMMERCIAL
TEXT SERIES

Text Series: Elementary School Mathematics
Addison Wesley Company (1968)
Authors: Eicholy, O'Daffer

Unusually well illustrated, the Addison Wesley materials represent perhaps the most complete intermediate mathematics program that the MINNEMAST Project has examined and found to be an acceptable successor to its primary materials: Aside from the Student Texts, this series contains a mathematical development of each topic designed for the teacher's use, a suggested list of supplementary materials for each chapter, objectives for each lesson, suggestions for the evaluation of each chapter, a short list of appropriate supplementary books as well as detailed suggestions for lesson presentation. Topics in the fourth grade materials that are felt to be particularly appropriate include the geometry of the circle and three-dimensional geometric forms, estimation, measurement, number theory, coordinate geometry. Their approach to rational numbers closely parallels that of the MINNEMAST Project. Multiple interpretations of mathematical concepts coupled with suggestions for the use of manipulative materials enhance the viability of this program. The Addison Wesley Program provides both a rich variety of activities and a sound mathematical approach. The Madison Project materials can provide the additional amount of the kind of explorative activities we feel are so essential to effective mathematical learnings.

Text Series: Sets and Numbers
Singer Company (1968, 1969)

The Singer Company Series, Sets and Numbers, provides a mathematical program that can be successfully adopted to succeed the MINNEMAST K-3 mathematics curricula. The authors of Sets and Numbers recognize the need for active student participation in the learning process and have designed many experiences accordingly. An attempt has been made to shift the responsibility for learning from the teacher to the student. Problem situations are sometimes designed so that the student is encouraged to play a central role in the development of the mathematical ideas. The authors of Sets and Numbers realize that learning takes place from the concrete to the abstract. Two-dimensional models are extensively used to provide the concrete framework from which mathematical ideas can ultimately be abstracted. Multiple embodiments are suggested for many of the concepts considered. It is hoped that schools adopting this series will attempt to procure many of the manipulative aids depicted in the textual materials.

The MINNEMAST K-3 mathematics program has been concerned with many of the topics treated in the 1-3 materials of the Singer Series. MINNEMAST students will therefore possess many of the skills and concepts required for suc-

cessful involvement in the fourth grade book of the Sets and Numbers series. The list of mathematical concepts and skills that have been developed by the MINNEMAST Project (pages 28 through 32) should be examined carefully so that discrepancies between these and the Singer Company Series can be discovered. Tests would be helpful in diagnosing areas where additional activities could be used to advantage. Tests would also reveal the extent to which supplementary activities might be required.

Text Series: SRA Elementary Mathematics Program
Science Research Associates, Inc. (1968, 1969)

Committed to variation of approach, the SRA Series generally presents a single mathematical idea in a number of different contexts. Realizing the importance of the role that visual and manipulative materials play in the effective learning of mathematics, the authors have developed Multimedia Manuals to correlate with each text.

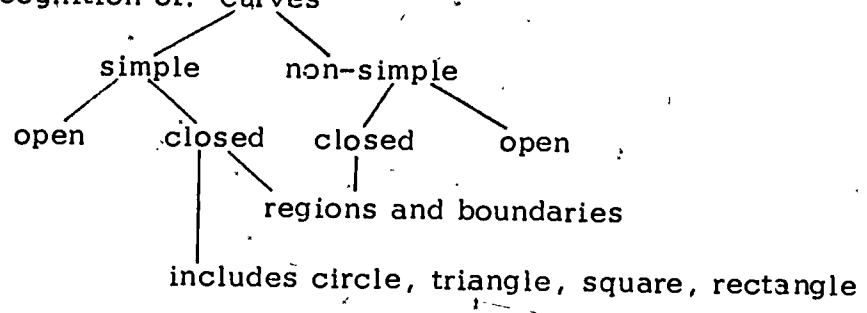
Although the materials suggested do not represent a complete picture of the breadth of materials to which the MINNEMAST Project would subscribe, these manuals are certainly a step in the right direction and they offer useful suggestions for sensory activities in the mathematics program at three levels of ability (remedial, average, enrichment). The teachers' editions are quite thorough from a pedagogical standpoint. They offer detailed suggestions for appropriate methods of presenting lessons. The teachers' manuals do not develop mathematical ideas for the teacher beyond those suggested for the students. In general, the mathematics is presented as a carefully developed finished product and students are seldom encouraged to develop their own rules and procedures. The topics considered are conventional in nature but are presented in a mathematically acceptable manner. As indicated above, students are often given multiple embodiments of important mathematical concepts. Coupled with the Madison Project materials, we feel that the SRA Series can provide a sound mathematical program for children in the intermediate grades.

MINNEMAST MATHEMATICS SKILLS AND CONCEPTS

Kindergarten

Unit 1, Watching and Wondering
Introductory unit — no specific math skills

Unit 2, Curves and Shapes
Recognition of: curves



Unit 3, Describing and Classifying
Placing objects in sets and subsets according to properties
Defining sets by listing
Equivalent sets
One to one correspondence
Set comparison (more, fewer)

Unit 4, Using Our Senses
No specific math skills

Unit 5, Introducing Measurement
Length: comparing lengths, ordering, reference object
Area: comparing areas, superposition, ordering
Volume: comparing volumes, ordering
Time: comparing durations of events

Unit 6, Numeration
Ordering sets
Equivalent sets
Counting 1 to 10
Introducing 0
Numerals 0 - 10

Unit 7, Introducing Symmetry
Recognition of: rotational symmetry, repeating patterns, bilateral symmetry

Unit 8, Observing Properties
Intersection of sets

Grade 1

Unit 9, Numbers and Counting
One to one correspondence (more, fewer)
Numerals from 0 to 20 (counting)
Ordering with symbols: $<$, $>$, $\doteq$

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Unit 10, Describing Locations
Introducing point, line, segment, locations
Naming of each of the above
Intersections of lines
Using a grid, betweenness, simple maps

Unit 11, Introducing Addition and Subtraction
Addition (1 digit by 1 digit), union of sets, arrays
Number line, introducing simple fractions
Numeration, 0 - 100

Unit 12, Measurement with Reference Units
Comparing lengths, ordering
Measuring length with standard units such as inches and centimeters
Imprecision of measurements
Perimeters

Unit 12, Continued

Comparing areas, superposition, reference objects
Distinguishing area from length
Comparing volumes, displacement, standard units
Comparing, ordering and measuring durations

Unit 13, Interpretations of Addition and Subtraction

Addition and subtraction on number line, slide rule
Properties of addition and subtraction, place value, numeration

Unit 14, Exploring Symmetrical Patterns

Rotational, translational and bilateral symmetries

Grade 2

Unit 15, Investigating Systems

No specific math skills

Unit 16, Numbers and Measuring

Ordering numbers, objects
Approximate nature of measurements
Fractional units
Circumferences, diameters
T-notation, place value
Adding 2-digit numerals on slide rule
The abacus, numerals through 999
Base 4 numeration, Roman numerals
Measuring weight

Unit 17, Introducing Multiplication and Division

Multiplication as repeated addition
Multiplication on the number line, on parallel number lines
Arrays
Multiplying 1 digit by 1 digit
Introducing division by means of simple fractions

Unit 18, Scaling and Representation

Math-related measurement, maps

Unit 19, Comparing Changes
Time - duration and clock reading
Plotting ordered pairs and weight/volume data

Unit 20, Using Larger Numbers
Place value to 999
All addition and subtraction facts
Introducing addition and subtraction algorithms
Estimation

Unit 21, Angles and Space
Points, lines, line segments
Rays, angles, angle measurement with clock protractor
Polygons: classification by properties such as number of sides, convexity or concavity, regularity or irregularity
Similar triangles, congruence
Tesselations (distinguishing patterns)
Polyhedra (transition to 3-dimensional shapes)

Unit 22, Parts and Pieces
Distinguishing between counting and amount measures
Fractional parts of objects and of sets
Adding and subtracting fractions on the number line
Fractions greater than 1, mixed fractions

Unit 23, Conditions Affecting Life
Bar graphs, coordinate graphs
Interpreting graphs

Unit 24, Change and Calculation
Complete addition and subtraction algorithms
Place value without limit (T - notation)
Graphing ordered pairs

Unit 25, Multiplication and Motion
Graphing ordered pairs (time/distance relations)

Unit 25, Continued
Interpreting graphs
Review of multiplication as repeated addition, as arrays, as Cartesian products
Multiplication using a graph with lines of certain slope
Understanding motion as the relation between time and distance (evident in the slope of a graph)

Unit 26, What Are Things Made Of?
Graphing volume/weight relations
Interpreting graphs
Model building of regular polygons for angle measurement
Transition from clock protractor to standard protractor

Unit 27, Numbers and their Properties
Developing standard multiplication algorithm for multiplying 1- and 2-digit numbers in column form
Practice with basic multiplication facts

Unit 28, Mapping the Globe
Measurement of area, angles, length
Model building
Properties of transformations

Unit 29, Natural Systems
Recognizing patterns and symmetries

It has been stated that the aim of the MINNEMAST Project is to exploit the interrelated nature of mathematics and science in a way that helps children understand the quantitative nature of observed phenomena. We believe that through this approach youngsters will learn about their environment and will also learn to recognize patterns, regularities and uniformities in the environment. This is important because understandings based on his own observations and data can help the child make valid predictions. The MINNEMAST Program presents the study of science as both knowledge of the environment and skills in eliciting answers from it. The children investigate a series of carefully planned science problems, gain understanding of each problem and learn procedures for problem solving. We believe that this method of teaching science is consistent with much of the contemporary research related to learning. It goes beyond the acquisition of facts toward the development of useful, lifelong attitudes about the endeavor of man that is called "active scientific investigation."

As an outcome of this approach, we believe students gain a clearer understanding of what learning is and make this a part of their behavior pattern. It is then incumbent on the teacher, principal and curriculum director to recognize the existence of this carefully nurtured problem-solving potential in children who have used the MINNEMAST material. Materials for Grades 4, 5 and 6 should offer continuing problem-solving challenges and pedagogic skills should be used to expand this ability.

GENERAL SUGGESTIONS

We would hope that a curriculum selected to follow the MINNEMAST Program would be one complementary to the teaching-learning mode already established. We would hope that the program would provide continuing opportunities for youngsters to investigate and discover. We would hope that the selected program would present topics as open-ended, investigative, and quantitatively designed.

The MINNEMAST K-3 materials provide an adequate background of information and skills so that the following transition illustrations should present few, if any, science transition problems. The suggested programs are representative of a wide range from which schools can make selections. There is no program existing today, other than MINNEMAST, that provides a coordinated approach to mathematics and science. We believe that within a few years such programs will be developed and published. Until that time, the teacher must look to programs that offer strong possibilities for investigation and quantification.

From a survey of many commercial science programs, it becomes evident that provisions have been made in almost all cases for the development of a teaching-learning mode that, at the discretion of the teacher, can range from textbook reading and occasional end-of-chapter questions to active involvement of students in the manifold operations of science. These include apparatus manipulation, problem solving, question-asking and individual and group science activities and investigations.

Consider the widely used text series, Concepts in Science, as an example of commercial materials that might be used. The books can be read and end-of-chapter questions can be answered by the children; or the books can serve as the nucleus for an active, investigative science program. The several skills expected of youngsters (instrument reading, graph interpretation, equipment manipulation and some understanding of sampling procedures) have been adequately developed in the coordinated activities of the MINNEMAST Program. Concepts in Science, for example, offers a related set of equipment packages for individual and group experimentation, has a related collection of films and film strips, and includes a package that provides suggestions for independent investigations. The teacher can organize and develop the suggested activities in such a way that quantitative relationships are perceived, and a quantitative approach to the teaching of science is continued even though the book-demands for quantification may be minimal or absent. This series will be mentioned again as specific transition models are discussed.

A second kind of elementary science program has been produced in this country in the past ten years. This kind emphasizes a quantitative approach to the understanding of natural phenomena: activity programs that involve a wide and exciting variety of investigations, and that consider science as much a way or process of finding out as it is a collection of facts representing a survey of parts of the vast body of knowledge called

science. Implicit in each of these programs is a development scheme that reduces the extent of the survey, and uses a smaller number of selected topics to develop a depth of knowledge through active participation in investigative activities by students. Programs that follow this pattern include SCIS (Science Curriculum Improvement Study), ESS (Elementary Science Study), SAPA (Science — A Process Approach, developed by the American Association for the Advancement of Science), and a collection of mathematics-oriented materials called Measure and Find Out (Scott, Foresman and Co.).

SCIENCE TRANSITION CRITERIA

In assessing science programs for continuity of the principles used in MINNEMAST and evidence of a teaching-learning mode in which students have developed competencies, these factors were the prime considerations:

- Open-endedness. Desirable lessons are those that set the stage for the children to find their own answers. This is in contrast to lessons that consistently present facts and do little more than support these facts with illustrations and the printed version of other people's reasoning.
- Active involvement of the students. Research evidence substantiates the need for children to be involved in doing operations. The ability to ask useful questions, to think of ways to answer these questions, to design and conduct experiments and to collect data and assess its meaning, is, we believe, as much

a purpose of science teaching as is the learning of facts.

- Quantitative idea development. The mathematics that children learn should be used as a tool in their investigative activities.

- Inquisitive attitudes. It is only when the child discovers that he can do something, succeed at it, and find out for himself — that he can build an "I can do" attitude. Failure is often the alternative when a child does not know how to learn and has not experienced the exhilaration of finding things out for himself.

- Depth vs. breadth. Content that represents a selected collection of conceptual schemes developed in depth, as contrasted with shallow surveys of a multitude of topics, is the final criterion on which we feel decisions can best be made.

Schools that are just beginning to use the MINNEMAST Curriculum will have certain freedoms of choice in their K - 6 program development not enjoyed by those already using it. For each, general and specific suggestions for transition procedures are offered for guidance purpose.

For schools planning to use MINNEMAST materials in Grades K - 3, there are flexibilities and alternatives. In particular, the third grade MINNEMAST materials can be stretched into Grade 4, and portions of the selected successor can be introduced in Grade 3.

The independent science packages of the ESS Program represent the first choice of MINNEMAST in science transition materials. It is suggested that several of the ESS units be inserted during Grade 3, and the MINNEMAST Program be extended into Grade 4. A second procedure involves the use of the Measure and Find Out materials. Through judiciously combining the Measure and Find Out program and selected ESS units, a balanced program that satisfies transition criteria as stated can be developed.

A second model involves the use of one or more commercial text series. Certain problems arise having to do with teaching mode and material appropriateness for students in the intermediate grades. Three commercial programs illustrate transition models that can satisfy transition criteria. Those included as illustrative are Concepts in Science, Experiences in Science and Science Through Discovery. We feel that when commercial series are selected it would be appropriate to omit certain selections that do not lend themselves to concrete activities, and to substitute activities from ESS units, Measure and Find Out or others specified in the illustrations. We suggest such alterations only after consideration of the materials and of the learning patterns of the children. These suggestions are made with reference to research in learning, and this project's extensive experience with materials in classrooms. Children in the intermediate grades are in the learning period designated by Piaget as "concrete." The implications of the research of

Piaget and co-workers have been interpreted by the MINNEMAST Project as supportive of a science program that provides continuing manipulative and investigative activities by students. Units that require active involvement should be given preference over those treated in a vicarious reading and discussion format. Further, certain concepts require formal intellectualization. According to Piaget, many children in the intermediate grades are not mature enough for formal operations. These concepts and conceptual schemes cannot be handled in a mode even approaching experiment or investigation. For this reason the illustrations suggest only minimal treatment of molecular theory and the fundamental particulate nature of matter. In their place we suggest the use of such ESS units as Kitchen Physics, Gases and Airs and Mystery Powders. There is a second reason for reducing emphasis on the development of concepts related to theories of the particulate nature of matter: when some of these students are in junior high, they will be able to operate on information in a formal way. At this time, among programs available, schools may select one called "Intermediate Physical Science" (IPS). Concepts of the particulate nature of matter are developed through a carefully planned series of experiences and activities. The student is given a chance to develop and consider general inferences about the nature of matter and is led through a historical-logical development of atomic theory. The aims of the IPS program, which include treating the learner as an active investigator, would be difficult to achieve if — through prema-

ture telling without the benefit of investigation — the answer were given before the question was asked.

This same omission policy is suggested for such topics as tree farming and molecular genetics. The importance of the topic is, again, not being questioned. We would recommend substitution of such ESS units as Brine Shrimp and Small Things or one of the genetics units developed at Webster College (WIMSA Project) entitled "On the Fly" and "Even Flies Remember."

Many of the units of the commercial text series deal with topics that can be handled in a quantitative, investigative mode. It will be necessary for the teacher to go beyond the text lessons in some cases. These units, for example, are treated in a straightforward, descriptive manner: Path of the Moon, Stars and Machines. In each, measurements can be made by youngsters and investigations can be conducted. The Illinois Astronomy Project also has units that would provide the teacher with many suggestions for making measurements and treating astronomical topics in a quantitative, investigative mode.

Schools planning to use SAPA or SCIS should use these programs in their entirety (K - 6). In general, both of these programs have been designed to provide a unified and comprehensive sequence of science experiences for elementary children. It is possible that certain somewhat independent MINNEMAST units, such as those on symmetry, would offer schools an opportunity to tailor programs to their specific needs. Living

Things in Field and Classroom, the MINNEMAST Handbook, is highly recommended as a valuable addition to any elementary science program that is selected.

The following five models represent, in the opinion of this author, acceptable transitional procedures. They are intended to illustrate the many ways schools, using materials appropriate to their philosophy, can capitalize on the investigative strengths that have been developed in children through MINNEMAST Program activities. The models are intentionally terse, for we believe that the best programs are developed when concerned, knowledgeable teachers, subject matter specialists, psychologists and children all work together to share ideas and build programs.

Transition models

1. The ESS Program
2. Measure and Find Out and ESS
3. Concepts in Science and selected insertions
4. Science through Discovery and selected insertions
5. Experiences in Science and selected insertions

Model 1: The ESS Program, Webster Division, McGraw-Hill

Grade 3

MINNEMAST Unit 23	Conditions Affecting Life
ESS	Light and Shadows
MINNEMAST Unit 26	What are Things Made Of?
ESS	Mystery Powders

ESS	Clay Boats
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 4

ESS	Ice Cubes
MINNEMAST Unit 28	Mapping the Globe
ESS	Brine Shrimp
ESS	Small Things
MINNEMAST Unit 29	Natural Systems
ESS	Crayfish
ESS	Peas and Particles
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 5

ESS	Batteries and Bulbs
ESS	Where is the Moon?
ESS	Rocks and Charts
ESS	Animal Activities
ESS	Pond Water
ESS	Pendulums
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 6

ESS	Behavior of Earthworms
ESS	Gases and Airs
ESS	Kitchen Physics
ESS	Senior Balancing
ESS	Colored Solutions
MINNEMAST Handbook	Living Things in Field and Classroom.

Model 2: The Measure and Find Out Program, Scott, Foresman and Company; and ESS Units

Grade 3	
MINNEMAST Unit 23	Conditions Affecting Life
MFO Book I	Activities 1 - 6
MINNEMAST Unit 26	What are Things Made Of?
MFO Book I	Activities 7 - 17
MFO Book I	Activities 18 - 23
MFO Book I	Activities 28 - 32
MINNEMAST Unit 28	Mapping the Globe
MINNEMAST Handbook	Living Things in Field and Classroom
Grade 4	
MFO Book II	Unit 1
ESS	Cardboard Carpentry
MFO Book II	Units 2 and 5
MINNEMAST Unit 29	Natural Systems
MINNEMAST Handbook	Living Things in Field and Classroom
Grade 5	
MFO Book II	Units 3 and 4
ESS	Peas and Particles
ESS	Small Things
ESS	Pond Water
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 6

MFO Book III	Unit I
ESS	Animal Activities
MFO Book III	Units 2 - 5
MINNEMAST Handbook	Living Things in Field and Classroom

An Ecology Study developed from Science Through Discovery, Book 5, Chapter 7; Water and its Pollution, Book 6, Chapters 6 and 7 (Air Pollution and Ecology) and the MINNEMAST Handbook, Living Things in Field and Classroom.

Model 3: Concepts in Science, Harcourt, Brace, World

Grade 3

MINNEMAST Program omitting Unit 28	
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 4

CIS	Units I through 4
ESS	Small Things
CIS	Unit 6
MINNEMAST Unit 28	Mapping the Globe
CIS	Unit 8 - Augment with Illinois Astronomy materials, Book I
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 5

CIS	Unit I
ESS	Gases and Airs
CIS	Units 3 through 8

MINNEMAST Handbook	Living Things in Field and Classroom

Grade 6

CIS	Units 1 through 3.
Either CIS	Unit 4
MFO III	Unit 5
or ESS.	Kitchen Physics
ESS	Bulbs and Batteries
MFO III	Unit 2
CIS	Unit 8 - Augment with On the Fly and Even Flies Remember (WIMSA Project)
CIS	Unit 9
MINNEMAST Handbook	Living Things in Field and Classroom

Model 4: Science Through Discovery, Singer/ Random House

Grade 3

MINNEMAST Program	Units 23 - 29
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 4

STD	Units 1 - 4.
STD	Unit 5 - Augment this with material from MFO III, Unit 4.
STD	Unit 6
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 5

STD	Units 1 - 4
ESS	Batteries and Bulbs
ESS	Gases and Airs
STD	Units 6 and 7
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 6

STD	Unit 1
ESS	Kitchen Physics
MFO	MFO, Book III, Units 3 and 4 (See above)
STD	Units 3 - 7
MINNEMAST Handbook	Living Things in Field and Classroom

Model 5: Experiences in Science, Webster Division, McGraw-Hill

Grade 3

MINNEMAST Unit 23	Conditions Affecting Life
EIS	Earth, Sun and Seasons
EIS	Heat
MINNEMAST Unit 26	What are Things Made Of?

EIS	Sound
EIS	Life Histories
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 4

EIS	Adaptations
MINNEMAST Unit 28	Mapping the Globe
EIS	Atmosphere and Weather
EIS	Geological Process
ESS	Gases and Airs
MINNEMAST Unit 29	Natural Systems
EIS	Ecology
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 5

Complete EIS Program	
MINNEMAST Handbook	Living Things in Field and Classroom

Grade 6

Complete EIS Program	
MINNEMAST Handbook	Living Things in Field and Classroom

THREADS THAT WEAVE THROUGH THE CURRICULUM

PROCESSES

Grade	Units	OBSERVATION						OBS.-GEN. LINK						GENERALIZATION					
		Observing	Describing	Classifying	Comparing	Ordering	Measuring	Symbolizing	Representing	Graphing	Communicating	Experimenting	Predicting	Simplifying	Approximating	Hypothesizing	Inferring	Model Building	Abstracting
K	1 Watching and Wondering	*	*							*					*		*		
	2 Curves and Shapes	*	*	*	*			*	*	*				*					
	3 Describing and Classifying	*	*	*	*					*				*					
	4 Using Our Senses	*		*	*					*	*								
	5 Introducing Measurement	*	*		*	*	*				*								
	6 Numeration				*	*		*											
	7 Introducing Symmetry	*	*	*	*					*									
1	8 Observing Properties	*	*	*	*	*				*	*			*					
	9 Numbers and Counting		*	*	*	*		*	*										
	10 Describing Locations	*	*			*		*	*	*	*								
	11 Introducing Add. and Subt.						*		*										
	12 Measurement with Ref. Units	*	*	*			*		*		*	*		*					
	13 Interps. of Add. and Subt.						*		*										
	14 Exploring Symmetrical Patterns	*	*	*	*						*	*							
2	15 Investigating Systems	*		*					*		*			*					
	16 Numbers and Measuring				*	*		*	*		*			*	*				
	17 Introducing Mult. and Div.	*							*										
	18 Scaling and Representation		*			*			*	*									
	19 Comparing Changes	*	*	*	*	*	*	*	*	*	*	*	*			*			
	20 Using Larger Numbers	*	*		*	*	*			*					*				
	21 Angles and Space	*	*	*			*	*	*		*							*	
	22 Parts and Pieces	*			*	*	*	*	*							*		*	
3	23 Conditions Affecting Life	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	24 Change and Calculations	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*		*
	25 Multiplication and Motion	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*		*
	26 What are Things Made Of?	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	27 Numbers and Their Properties	*		*	*	*		*						*	*		*		*
	28 Mapping the Globe	*	*	*	*	*	*	*	*		*	*	*		*	*	*	*	*
	29 Natural Systems	*	*	*	*	*	*	*		*	*	*	*	*		*	*		*

SUBJECTS

MATHEMATICS — Math-Science — SCIENCE

Real Numbers — Geometry — Formal Concepts — Topics

	Number Line	Number Theory	Arithmetic	Continuity	Prob. & Stat.	Sets & Groups	Shapes Config.	Euclidean Geom.	Topology	Symmetry	Dimension	Transformations	Functions	Systems	Interaction	Change	Reversibility	Invariance	Space	Time	Matter	Force & Field	Life
2							*		*								*		+				
3						*								*			*				*		*
4											*			*	*				*		*		*
5		*		*			*	*			*								*	*			
6	*		*																				
7										*			*				*		*				*
8						*	*							*		*		*	*		*		*
9	*		*												*			*					
10	*			*			*	*			*								*				
11	*		*																				*
12	*	*		*		-	*	*			*				*			*	*	*			
13	*		*																				*
14								*		*			*					*	*				*
15						*								*	*	*	*	*			*	*	*
16	*		*													*		*			*	*	
17	*		*										*										
18				*			*				*		*					*	*				*
19	*		*	*		*					*			*	*	*	*	*	*	*	*			*
20	*	*	*	*				*						*		*			*		*			
21	*		*	*			*	*		*	*		*	*				*	*			*		*
22	*	*	*	*				*						*					*	*				
23	*		*				*						*	*	*	*	*	*	*			*		*
24	*	*	*	*	*	*	*	*			*			*	*		*		*	*		*		
25	*	*	*		*	*								*	*		*			*				
26	*			*	*	*	*	*			*		*	*	*	*	*	*	*		*			
27	*	*	*			*				*				*	*							*	*	*
28	*		*	*		*	*	*	*	*	*		*	*		*		*	*		*			*
29	*		*				*			*			*	*	*	*			*	*	*	*		*

KEEPING CURRENT

Perhaps one of the most significant contributions that the MINNEMAST Project has made to education is that its curriculum demonstrates the feasibility and advantages of coordinating the teaching of mathematics and science. At any rate, present interest in such coordination is high. The authors believe that when sufficient federal funds are again available for this purpose, significant amounts will be allocated to the development of coordinated curricula.

At present there are two projects concerned with the integration of mathematics and science. You may wish to keep abreast of the materials they are producing:

USMES (Unified Science and Mathematics in the Elementary School) Project
Education Development Center
55 Chapel Street
Newton, Massachusetts

NUFFIELD Project of Great Britain
Materials are handled in the United States by:
John Wiley and Sons Publishing Company
605 Third Avenue
New York, New York 10016